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Body fat reference curves for healthy Turkish children and adolescents

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Abstract Childhood obesity is a major worldwide health problem. In addition to body mass index (BMI), body fat percentiles may be used to predict future cardiovascular and metabolic health risks. The aim of this study is to define new age- and gender-specific body fat centiles for Turkish children and adolescents. A total of 4,076 (2,276 girls, 1,800 boys) children and adolescents aged 6–18 years were recruited for this study. Total body fat was measured by a bioelectrical impedance noninvasive method. Body fat percentiles were produced by the LMS method. The body fat percentile curves of boys appear to rise from age 6 to 12 years and then slope downwards to age 15 years and then flatten off. The body fat % percentiles of girls increased until 14 years of age through 75th to 97th percentiles and then slope downwards, but through the third to 50th percentiles, they showed a downward slope after 14 years old. Conclusions: Since BMI may not always reflect body fat content, direct assessment of adiposity by a practical method would be significantly useful for clinical decisions. Therefore, this study provides normative data for body fat percentage in healthy Turkish children and adolescents. To this goal we used a practical and clinically applicable method. These references can be useful for evaluation of overweight and obesity.

Keywords Body fat · Children · Adolescents · Obesity

Introduction

Studies about the prevalence of obesity in the childhood population are relatively new compared with studies in adults. Few studies about obesity in the Turkish population exist when compared with other studies, so commonly used references that describe obesity are lacking [22]. Although various studies examine some commonly used parameters

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(body mass index (BMI), waist circumference, mid upper arm circumference, skin fold thickness) to describe obesity, we do not have body fat percentiles for Turkish children and adolescents [4, 11, 12, 20]. The dramatic increase in childhood obesity has been reported by authors worldwide [14].

Body mass index references are currently used to asses obesity, and widely accepted cutoff values have been published [6, 8, 9]. Several authors reported that there are some limitations to BMI in distinguishing between fat and lean mass [9]. The result of metabolic processes leads to both increased and varied quantity of fat accumulation (primarily excess central fat accumulation) [18–20]. Skinfold thickness references are used to explain this difference [4]. Although measuring skinfold thickness is a practical method, inter-observer variability and need for qualified staff limits its widespread use and the reliability of this method in some situations. Using bioelectrical impedance (BIA) measurements to assess the quantity of body fat accumulation and segmental distribution of this fat content is considered relatively expensive when compared to

measuring skinfold thickness, but determining body fat with BIA is much more practical, provides segmental distribution, and can easily be used in population screening as well as used in daily practice [19, 21].

We planned this study to obtain body fat references for Turkish children aged 6–18 years old. These references can then be used in clinical practice to assess overweight and obese children. Additionally, our data may be compared with other studies and be used in determining adiposity distribution in other countries.

Material and methods

Subjects

Data were obtained from the study of the Determination of Anthropometric Measures of Turkish Children and Adolescents (DAMTCA II) between September 2007 and May 2008. The DAMTCA II study was performed in

Table 1 Mean (SD), median (minimum–maximum) fat % for Turkish children age of 6–18 years and comparisons of the means

Age	Boys			Girls			t value	p value
	n^a	Mean (SD)	Median (min–max)^a	n^a	Mean (SD)	Median (min–max)^a		
6	55	20.11 (4.0)	18.70 (14.90–35.80)	71	22.45 (3.4)	21.70 (14.50–31.70)	4.304	<0.001
6.5	70	19.66 (3.4)	19.10 (13.10–33.30)	65	22.03 (3.9)	21.50 (16.60–38.00)	4.541	<0.001
7	88	20.65 (4.7)	19.30 (13.80–41.30)	88	22.83 (4.2)	21.95 (16.40–41.10)	3.927	<0.001
7.5	70	20.59 (4.4)	19.45 (14.00–32.70)	82	22.88 (4.4)	21.75 (16.40–39.00)	3.512	<0.001
8	90	20.89 (4.9)	19.15 (13.90–36.90)	76	22.69 (4.7)	21.70 (16.40–37.50)	2.607	0.010
8.5	79	20.83 (5.5)	19.10 (13.60–36.10)	99	22.56 (4.7)	21.60 (16.10–43.40)	2.602	0.010
9	77	21.54 (6.4)	19.10 (13.70–39.60)	74	22.92 (4.7)	22.00 (12.70–34.20)	1.851	0.066
9.5	69	21.17 (6.9)	19.40 (9.80–46.90)	76	23.69 (5.3)	22.85 (15.30–41.00)	3.032	0.003
10	83	21.08 (6.3)	18.90 (12.40–39.80)	81	23.65 (5.1)	23.20 (15.80–36.80)	3.221	0.002
10.5	86	20.51 (5.7)	19.20 (11.20–44.30)	105	24.88 (5.9)	23.60 (15.90–42.90)	5.902	<0.001
11	73	21.41 (6.8)	19.90 (12.30–43.20)	60	23.56 (4.9)	22.65 (15.60–36.10)	2.631	0.010
11.5	79	18.48 (4.5)	17.70 (9.50–32.60)	62	24.74 (5.9)	23.85 (15.50–42.90)	7.800	<0.001
12	58	21.21 (7.0)	18.60 (10.20–40.50)	56	24.76 (5.6)	22.90 (17.10–39.00)	3.173	0.002
12.5	64	19.00 (6.9)	16.80 (9.80–45.70)	106	24.16 (4.4)	23.40 (14.30–34.60)	6.940	<0.001
13	74	19.09 (6.3)	17.10 (10.10–38.70)	82	24.45 (5.8)	22.65 (10.40–43.00)	6.542	<0.001
13.5	67	17.76 (5.4)	16.00 (10.90–35.00)	81	26.81 (5.8)	25.80 (18.30–42.70)	10.654	<0.001
14	63	17.37 (6.6)	15.10 (8.10–41.40)	56	26.89 (5.4)	26.15 (15.80–38.80)	9.493	<0.001
14.5	91	16.44 (5.3)	15.20 (9.60–40.60)	97	27.42 (5.7)	27.50 (14.40–44.10)	16.240	<0.001
15	93	16.71 (5.2)	15.40 (6.50–30.40)	151	24.74 (6.0)	24.50 (8.30–40.10)	12.050	<0.001
15.5	132	16.18 (5.3)	14.90 (7.90–35.80)	247	24.27 (6.7)	24.20 (4.50–41.30)	13.748	<0.001
16	103	15.76 (5.1)	14.70 (8.50–34.30)	239	24.87 (6.6)	24.20 (11.30–42.70)	14.256	<0.001
16.5	125	17.18 (6.0)	15.60 (7.50–37.60)	198	24.65 (6.7)	24.65 (9.20–43.70)	11.393	<0.001
17	56	16.45 (4.7)	15.20 (8.50–35.20)	92	24.25 (5.8)	24.95 (12.00–34.80)	10.608	<0.001
17.5	31	16.44 (5.2)	15.30 (9.10–30.30)	47	24.76 (7.5)	24.00 (9.20–47.70)	5.670	<0.001
18	15	17.35 (5.5)	16.60 (9.30–30.70)	13	23.42 (6.9)	21.30 (14.80–40.00)	3.261	<0.001

^{a} A total of 4076 children and adolescent (1,800 boys, 2,276 girls)

Kayseri province which has more than 1,000,000 inhabitants and a leading industrial trade center in Turkey. Children and adolescents from 19 schools in Kayseri, Turkey, were recruited in this study. The study protocol was approved by the Ethics Committee of Erciyes University and the administration of the local educational authority. The sampling design of the study was a two-stage probability sampling for school children living in Kayseri.

In the first stage, students were selected by the stratified sampling method according to socio-economic levels of their parents. In 699 Kayseri schools, 20 of them (nine primary, 11 secondary) were randomly selected. Children and adolescents aged 7 to 18 years were randomly selected from enrolled schools. These children who did not attend school on the study date were visited again to invite them to participate in the study. Five percent of the children and adolescents or their parents refused to participate in the study or they could not be found at the school. Children with known growth disorders and those who used any kind of medication were excluded from the study. Children and adolescents whose height and weight were between the

third and 97th percentiles were selected. Those whose height and weight were lower than the third percentile or higher than the 97th percentile were removed from the study. Chronological age was calculated as the decimal age by subtracting the observation date from the birth date. Each year elapsed from their birthdates was noted as one age. Parents' written consent was obtained prior to the study, and the procedures were in accordance with those outlined by the Declaration of Helsinki.

Measurements

All measurements were performed by well-trained technicians. Height was measured to the nearest 1 cm by a portable Seca stadiometer twice, and the average was used. Total and segmental body fat was measured by a segmental body composition analyser, Tanita BC-418MA (Tanita Corporation, Tokyo, Japan) with correction for light indoor clothing. Children were asked to refrain from food or drink in the hour prior to measurement, to empty their bladders before the measurement, and to wear light clothes. The analyzer measures body fat % to the nearest 0.1% based on age, gender,

Table 2 The 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles of Turkish boys

Boys										
Age	3 p	5 p	10 p	25 p	50 p	75 p	85 p	90 p	95 p	97 p
6.00	15.49	15.86	16.50	17.75	19.49	21.83	23.45	24.77	27.16	29.11
6.50	15.39	15.78	16.43	17.71	19.51	21.93	23.62	25.00	27.52	29.58
7.00	15.28	15.68	16.35	17.66	19.53	22.05	23.83	25.28	27.95	30.16
7.50	15.14	15.55	16.24	17.60	19.54	22.18	24.06	25.60	28.45	30.83
8.00	14.98	15.40	16.11	17.52	19.54	22.31	24.29	25.92	28.97	31.53
8.50	14.78	15.22	15.95	17.41	19.51	22.41	24.50	26.23	29.48	32.24
9.00	14.56	15.01	15.76	17.27	19.45	22.48	24.68	26.51	29.96	32.91
9.50	14.31	14.77	15.54	17.10	19.36	22.52	24.82	26.74	30.37	33.49
10.00	14.03	14.50	15.30	16.90	19.23	22.50	24.89	26.89	30.68	33.93
10.50	13.72	14.19	15.01	16.65	19.04	22.41	24.87	26.93	30.84	34.18
11.00	13.35	13.84	14.67	16.34	18.78	22.22	24.73	26.83	30.80	34.18
11.50	12.94	13.43	14.27	15.96	18.43	21.90	24.44	26.55	30.54	33.91
12.00	12.50	13.00	13.84	15.53	18.01	21.50	24.03	26.14	30.09	33.41
12.50	12.04	12.53	13.37	15.06	17.53	21.00	23.51	25.58	29.45	32.66
13.00	11.56	12.05	12.88	14.56	17.01	20.44	22.90	24.92	28.66	31.74
13.50	11.10	11.58	12.40	14.06	16.48	19.84	22.23	24.19	27.78	30.70
14.00	10.67	11.15	11.96	13.60	15.98	19.27	21.59	23.48	26.90	29.66
14.50	10.33	10.80	11.62	13.25	15.60	18.82	21.07	22.90	26.17	28.77
15.00	10.08	10.55	11.37	13.00	15.34	18.51	20.71	22.48	25.62	28.09
15.50	9.91	10.40	11.22	12.86	15.20	18.35	20.51	22.23	25.26	27.62
16.00	9.86	10.35	11.19	12.86	15.23	18.38	20.53	22.22	25.17	27.44
16.50	9.91	10.41	11.28	12.99	15.41	18.60	20.75	22.43	25.33	27.54
17.00	9.99	10.52	11.41	13.18	15.65	18.89	21.04	22.71	25.58	27.73
17.50	10.08	10.63	11.55	13.38	15.92	19.19	21.36	23.02	25.85	27.95
18.00	10.18	10.74	11.71	13.59	16.19	19.52	21.69	23.35	26.14	28.20

Table 3 The 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentiles of Turkish girls

Girls										
Age	3 p	5 p	10 p	25 p	50 p	75 p	85 p	90 p	95 p	97 p
6.00	17.72	18.12	18.77	20.02	21.72	23.90	25.35	26.48	28.45	29.97
6.50	17.57	17.98	18.65	19.96	21.74	24.02	25.55	26.74	28.82	30.43
7.00	17.43	17.85	18.56	19.92	21.78	24.17	25.77	27.02	29.20	30.89
7.50	17.30	17.74	18.47	19.89	21.83	24.33	26.00	27.31	29.59	31.35
8.00	17.19	17.64	18.41	19.88	21.91	24.51	26.25	27.61	29.98	31.81
8.50	17.11	17.59	18.38	19.92	22.03	24.75	26.56	27.97	30.42	32.30
9.00	17.08	17.58	18.41	20.02	22.22	25.05	26.93	28.39	30.91	32.84
9.50	17.09	17.61	18.48	20.17	22.47	25.41	27.35	28.85	31.44	33.40
10.00	17.11	17.66	18.58	20.34	22.74	25.80	27.80	29.34	31.97	33.95
10.50	17.14	17.72	18.68	20.53	23.04	26.20	28.25	29.83	32.49	34.47
11.00	17.16	17.77	18.78	20.72	23.34	26.60	28.70	30.29	32.96	34.93
11.50	17.17	17.81	18.88	20.92	23.64	27.00	29.14	30.75	33.42	35.36
12.00	17.16	17.84	18.97	21.11	23.95	27.40	29.57	31.19	33.85	35.76
12.50	17.13	17.85	19.04	21.30	24.25	27.79	29.99	31.61	34.25	36.13
13.00	17.05	17.81	19.08	21.45	24.53	28.16	30.38	32.01	34.62	36.46
13.50	16.90	17.72	19.06	21.56	24.75	28.47	30.71	32.34	34.92	36.72
14.00	16.65	17.52	18.95	21.57	24.88	28.67	30.93	32.54	35.09	36.84
14.50	16.30	17.22	18.72	21.47	24.89	28.74	30.99	32.60	35.09	36.80
15.00	15.85	16.83	18.41	21.28	24.80	28.68	30.93	32.51	34.96	36.62
15.50	15.36	16.40	18.06	21.04	24.65	28.57	30.81	32.38	34.78	36.39
16.00	14.88	15.97	17.72	20.81	24.51	28.46	30.69	32.24	34.60	36.18
16.50	14.39	15.55	17.38	20.59	24.37	28.36	30.58	32.12	34.44	35.98
17.00	13.89	15.11	17.03	20.37	24.23	28.25	30.47	31.99	34.28	35.79
17.50	13.37	14.66	16.68	20.14	24.09	28.13	30.34	31.85	34.11	35.59
18.00	12.81	14.18	16.31	19.91	23.94	28.01	30.21	31.71	33.93	35.37

Fig. 1 The 3rd, 5th, 10th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentile curves of Turkish boys
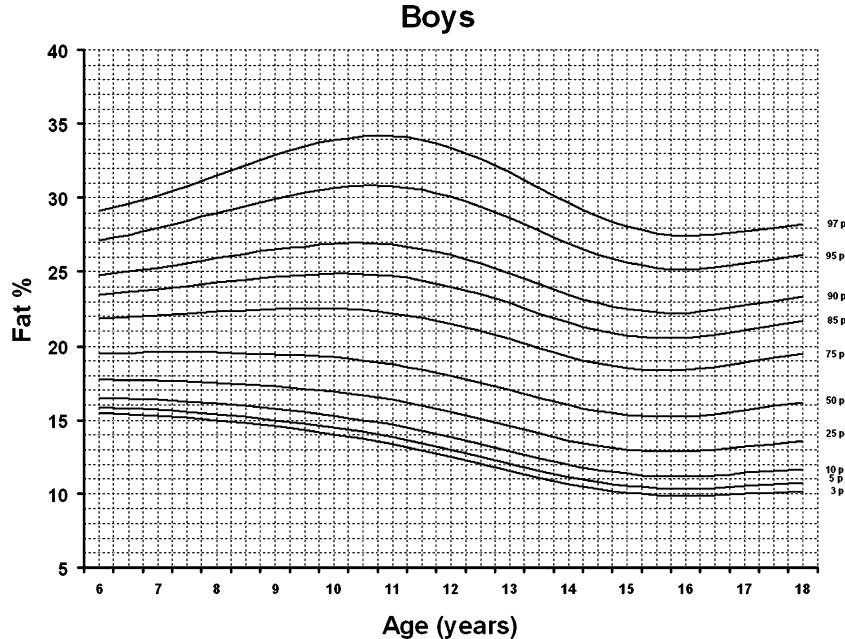
Fig. 2 The 3rd, 10th, 5th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th percentile curves of Turkish girls
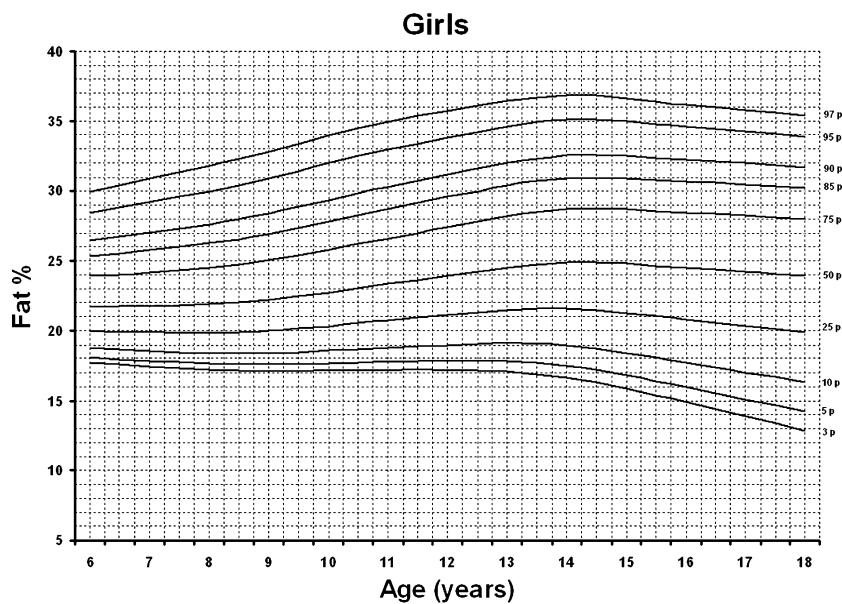

height, and weight. Children and adolescents stood with bare feet over the analyzer holding handgrips in each hand.

Statistical analysis

Construction of the centile curves was performed with the LMS Chart Maker Pro version 2.3 software program (The Institute of Child Health, London), which fits smooth centile curves to reference data [5]. This method summarizes percentiles at each age based on the power of age-specific Box-Cox power transformations that are used to normalize data. These three quantities depend on age. The final curves of percentiles are produced by three smooth curves representing *L* (Lambda; skewness), *M* (Mu; median), and *S* (Sigma; coefficient of variation) [5].

To compare body fat % for each whole year (e.g., 7.00–7.99 years, etc.) within sex were calculated by SPSS version 13.0 (Chicago, IL, USA). The mean body fat % of Turkish children and adolescents was compared and girls' body fat % was found to be significantly higher than boys through 6–18 years except for 9.0 years (Table 3).

Results

The data less than third percentile and higher than 97th percentile body fat % of 4,295 (1,891 boys, 2,404 girls) children were removed to delete outlying values and to get homogeneous data distribution (Table 1). Then a total of 4,076 (2,276 girls, 1,800 boys) children and adolescent

Fig. 3 The comparison of the 50th percentile curves of Asian, UK, and Turkish girls
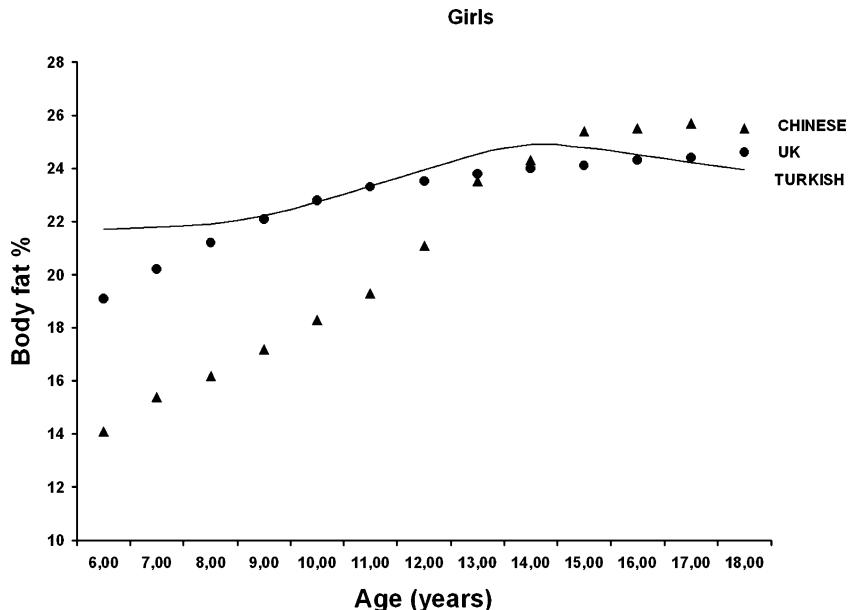
body fat % data were used to get smoothed percentiles of third, fifth, 15th, 25th, 50th, 75th, 85th, 90th, 95th, and 97th by age and gender.

Tables 2 and 3 and Figs. 1 and 2 show the full set of centiles and centile curves for boys and girls aged 6–18 years in 6-month intervals. The calculated mean (SD) and median (min–max, minimum–maximum) values for each gender and age group are also shown in Table 1 to provide a comparison of data with other studies.

The body fat percentile curves of boys appear to rise from age 6 to age 12 years and then slope downwards to age 15 years and then flatten off. The body fat percentiles of girls shows upward convergence until 14 years of age for 75th–97th percentiles and then became flat, but third to 50th percentile curves showed a downward slope after 14 years old.

The comparison of 50th percentile curves of both gender showed that 50th percentile body fat of girls was higher than boys (the difference at 6 years old children were 2.23%) through 6–18 years. This difference became significant after 8 years old and became 7.85% in 18-year-old adolescents. We found that the maximum difference between each gender was 9.46% in 15 years old adolescents (Fig. 3).

We showed the 50th percentile curves of Turkish and UK children and adolescents to compare body fat % 50 percentile curves of two different populations (Fig. 4).

When we compared the Asian, UK, and Turkish female children, the 50th percentile curve of Asians was significantly lower than Turkish and UK children at 6 years old, and later the 50th percentile curves of Asians became similar with Turkish and UK adolescents aged 14.5–18 years (Fig. 3) [15, 17, 23]. For boys the comparison of the 50th percentile curves of the three regions was inconsistent with each other through 6.0–18.0 years (Fig. 4).

The comparison of means between Turkish boys and girls showed that, other than 9 years old, the body fat % of girls were significantly higher than boys. The ratio of children whose body fat % was over the 85th percentile was 1% for boys and 17.5% for girls.

Discussion

Several anthropometric measurements such as waist circumference, mid upper arm circumference, and neck circumference can be used to assess body fat distribution in central and peripheral parts of body [4, 11, 12]. Dual-energy X-ray absorpsiometry is the most reliable method to assess body fat content and distribution, but it is both an expensive and impractical method for both epidemiological studies and clinical practice [13]. The other two most commonly used methods to determine body fat content and distribution are bioelectrical impedance and skinfold thickness [3, 4, 7, 10, 19].

This is the first study to offer body fat percentiles as measured by BIA in Turkish children and adolescents between 6 and 18 years of age. We found that in both genders body fat % increases during puberty (Figs. 1 and 2). After the pubertal period, boys body fat % decreases to a certain point and then remains constant thereafter. Body fat % of girls show similar convergence with boys for upper percentiles (85th and over), but for the 75th and lower percentiles we observed a gradual decrease (in place of remaining constant) after a certain point. In this study the comparison of body fat percentiles between boys and girls shows that girls experience a significant decrease in body fat % after 14 years old in the 75th and lower

Fig. 4 The comparison of the 50th percentile curves of Asian, UK, and Turkish boys
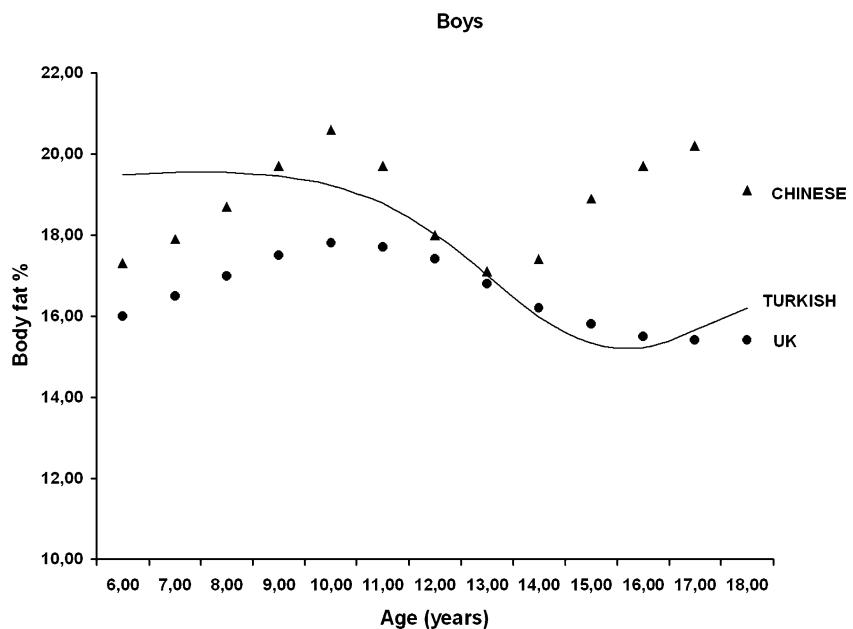
percentiles. We considered that girls who exhibited excess fat kept their body fat while girls who did not exhibit did not keep their body fat after puberty.

Williams at al. provides cutoff for total body fat % as 25% for males and 30% for females [24]. Mc Carthy recommends that body fat % between 85th and 95th percentile viewed as excess fat and over 95th percentile as obesity [15]. BIA over the 85th percentile may be considered as excessive body fat [17, 23]. In a study published by Mc Carthy et al. body fat percentiles of 85th and 95th percentile were defined as respectively excess fat and obesity cutoffs [15]. The rationale of Mc Carthy et al. was the similarity of body fat percentile curves (85th and 95th) with BMI curves which were defined by the International Obesity Task Force [15]. No consensus has been reached on the diagnosis of obesity by means of body fat % [1, 3, 7, 10, 16, 25]. Although a limited number of studies define obesity by BIA we consider that determining body fat % would provide additional and useful information to evaluate obesity.

In those cases where BMI is in a normal range, but the body fat content is higher or normal range than BIA would provide significantly important additional data. On the contrary high body mass index does not indicate high body fat content or a body fat distribution disorder [1, 2]. In both conditions mentioned above, BIA may be a reliable alternative method to be used in routine clinical practice [25].

This study provides body fat references which can be used to base a clinical judgment for obesity in Turkish children and provides data to compare with other countries.

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